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(54) Method of manufacturing optical components

(57) A method of improving the optical properties of a surface of an optical component wherein the surface is subject to a beam of radiation, e.g. laser radiation, to cause localised annealing of the surface. Where the component is a planar optical waveguide comprising a substrate with a light transparent surface layer having a refractive index higher than the substrate material formed on the substrate, the exposed face of the surface layer is subjected to the beam, so as to cause melting of the surface layer.

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SPECIFICATION

Methods of manufacturing optical c mpon nts

This invention relates to methods of manufacturing optical components.

Fabrication techniques for the production of optical components, for example machine polishing, often result in the production of defects such as scratches and pits on the surface of the component. Furthermore, where the component is fabricated from a monocrystalline material, the polishing may also result in the formation of the polycrystalline layer under the surface. Diffusion and ion implantations into polished surfaces also degrade the optical quality of the surface. For these reasons optical components often exhibit unacceptably high optical loss due to scatter.

It is an object of the present invention to provide a method of manufacturing an optical component wherein these difficulties are alleviated.

According to the present invention in a method of manufacturing an optical component, the optical properties of a surface or a surface layer of the component are improved by subjecting the surface or surface layer to a beam of radiation so as to cause localised annealing of said surface or surface layer.

Preferably the radiation is laser radiation.

In one particular method in accordance with the invention said component is a planar optical waveguide comprising a substrate with a light transparent surface layer having a refractive index higher than the substrate material formed on the substrate, and said method comprises subjecting said surface layer to a beam of radiation so as to cause melting of said surface layer.

In such a method preferably the whole of said surface layer is irradiated simultaneously. Preferably the radiation is applied in the form of an intense pulse of short duration.

Three methods in accordance with the invention will now be described by way of example.

In the first method to be described the scatter exhibited by a mirror for use in a laser ring gyroscope is minimised.

To this end a beam of radiation from a CO_2 laser at a wavelength of 10.6 microns is scanned over a face of a fused silica or a low expansion silica-based substrate prepared using conventional techniques for use in manufacture of a mirror for a laser ring gyroscope. The beam is scanned over an area larger than the substrated surface by means of a rotating mirror, the inclination of which is varied so that the beam m ves in a random patt rn over the whole of the substrate face. Th beam causes local melting of the substrate surface. As a result surface defects in the substrate, such as scratches and pits resulting from conventional polishing techniques used to finish the substrate prior to laser annealing, are largely eliminated, with consequent reduction in scattering of light reflected by a mirror formed by application of appropriate refractive coatings to the substrate surface.

In the second method to be described the scatter exhibit d by an optical waveguide comprising a light transparent layer on the surface of a substrate is reduced.

The waveguide is formed on a mono cyrstallin lithium niobate ($LiNbO_3$) substrate having a thickness typically of 0.5 millimetres, the substrate being finished in conventional manner by polishing both of its main faces.

Titanium is then diffused into one main face f the substrate in conventional manner to form a light transparent surface layer on the substrate of thickness about 2 μm and having a refractive index higher than lithium niobate, this process possibly also leading to further defects such as the formation of polycrystalline material within the surface layer, and unevenly diffused titanium.

To overcome this the surface layer is then melted by simultaneously subjecting the whol of the exposed surface of the titanium doped surfac layer to radiation from a CO_2 laser for four seconds at an energy density of 25 watts per square centimetre.

In one planar optical waveguide fabricated as described above the back scatter was found to be 0.32% whereas a back scatter of 1.08% was obtained for the waveguide before the annealing process. Furthermore the transmittance of the surface layer was found to have improved slightly after the annealing process e.g. from 72.5% to 77% for light of wave number 1500 per centimetre.

The reduction in back scatter was the same when the surface layer was exposed to the radiation for 15 seconds instead of 4 seconds, indicating that 4 seconds was sufficient time to melt the whole of the surface layer. Thus by this method surface defects such as pits and scratches, as well as any subsurface polycrystalline material are removed as well as aiding the titanium to evenly diffuse through th surface layer.

The same annealing technique may also suitably be employed in the fabrication of optical waveguides on lithium niobate substrates by alternative methods such as ion exchange or out-diffusion.

It will be appreciated that in the method according to the invention the melting process is preferably carried out as rapidly as possible and heating restricted as nearly as possible to the surface layer of the substrate forming the waveguide. Thus, for a required annealing effect the wavelength, energy density and dwell time of the radiation must be carefully chosen with regard to the absorption coefficient and thermal diffusivity of the target material.

For a substrate of lithium niobate, radiation from a CO_2 laser at 10.6 μm is suitable since lithium niobate is transparent only for radiation in the waveband 0.37 μm to 5 μm. An alternative radiation source which might be used is an ArF laser producing radiation at 0.2 μm but since lithium niobate is susceptible to damage by short

wave length light, the 10.6μm wav length radiation from a CO_2 is probably more suitable.

It will be understood that the invention is applicable to planar optical waveguides formed on monocrystalline substrates other than lithium niobate, for example, waveguides on gallium arsenide substrates when the dopant for the surface layer is suitably aluminium.

In the third method to be described an optical waveguide structure formed in a surface layer of a substrate comprising a compound of elements in groups III to V of the periodic table is annealed using laser radiation to remove defects in the layer. The structure typically comprises a hetero-epitaxial structure in the system $GA_x AL_{1-x}As$, perhaps with additional doping, e.g. by ion implantation, on a gallium-arsenide substrate to form a graded index structure and semiconductor devices such as light emitters and sensors co-operating with the optical waveguide may be formed in the substrate to form an integrated structure with the optical waveguide.

The laser radiation may be simultaneously mployed for the purpose of controlling or modifying the doping of the layer. For example, successive layers of $Ga_xAl_{1-x}As$ may be formed within the substrate by conventional methods such as ion implantation, or laser photo-chemistry. The energy of the laser radiation used to anneal each layer is then controlled such that each layer will diffuse to a different level within the substrate.

CLAIMS

1. A method of manufacturing an optical component in which the optical properties of a surface or a surface layer of the component are improved by subjecting the surface or surface layer to a beam of radiation so as to cause l calised annealing of said surface or surface layer.

2. A method according to Claim 1 in which said radiati n is laser radiation.

3. A method according to either of the preceding claims in which said improvements comprise reduction of surface defects on said surface.

4. A method according to Claim 3 in which said beam is scanned over said surface.

5. A method according to any one of Claims 1 to 3 in which said component is an optical waveguide structure formed in a surface layer of a substrate and said radiation removes defects within said surface layer.

6. A method according to Claim 5 in which said component is a planar optical waveguide comprising a substrate with a light surface layer having a refractive index higher than the substrate material formed on the substrate, and said method comprises subjecting said surface layer to a beam of radiation so as to cause melting of said surface layer.

7. A method according to Claim 6 in which the whole of said surface layer is irradiated simultaneously.

8. A method according to Claim 6 or Claim 7 in which the radiation is applied in the form of an intense pulse of short duration.

9. A method according to any one of the preceding Claims in which said optical component is formed from a monocrystalline material, and said radiation causes any polycrystalline material in said surface layer to become monocrystalline.

10. A method of manufacturing an optical component substantially as herein before described.

11. An optical component manufactured by a method according to any one of the preceding claims.

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